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## FAX TRANSMITTAL COVER PAGE

DATE: February 2, 1994

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*SWP*

MESSAGE:

As we discussed, enclosed is a project summary for the Acid Extraction Treatment System, which includes data for the Pedricktown site, as well as an overall summary of the work performed. Also enclosed are several sections from our final report on the project, which give more details on the Pedricktown soil.

Please note that our economic calculations include \$300/ton for disposing the residual metal hydroxides. This cost tends to represent approximately 15% of the overall system cost. The cost estimates also assume that the plant is operated only 1 shift per day (a very conservative assumption). Given the recent decrease in the cost of disposal, and assuming that the plant is operated more than one shift per day, the cost of treatment will drop between 15 and 30%. Therefore, in my view, the system is still very competitive with stabilization and off-site disposal.

TOTAL NUMBER OF PAGES (INCLUDING TRANSMITTAL SHEET): 75

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## PROJECT SUMMARY

### ACID EXTRACTION TREATMENT SYSTEM FOR TREATMENT OF METAL CONTAMINATED SOILS

Stephen W. Paff, Brian E. Bosilovich, and Nicholas J. Kardos

#### ABSTRACT

The Acid Extraction Treatment System (AETS) is intended to reduce the concentrations and/or leachability of heavy metals in contaminated soils so the soil can be returned to the site from which it originated. The objective of the project was to determine the effectiveness and commercial viability of the process. The report summarized here is an account of the activities conducted during the project, the experiments performed, results and conclusions.

A pilot-scale AETS system was used to treat 5 different soils containing different combinations of seven heavy metals. The study showed that AETS is capable of treating a wide range of soils, and reducing the TCLP metals to below the RCRA limits. The AETS can, in most cases, treat the entire soil, with no separate disposal or stabilization of the clay fines needed. The estimated treatment costs are between \$80 and \$180 per cubic yard.

This project summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

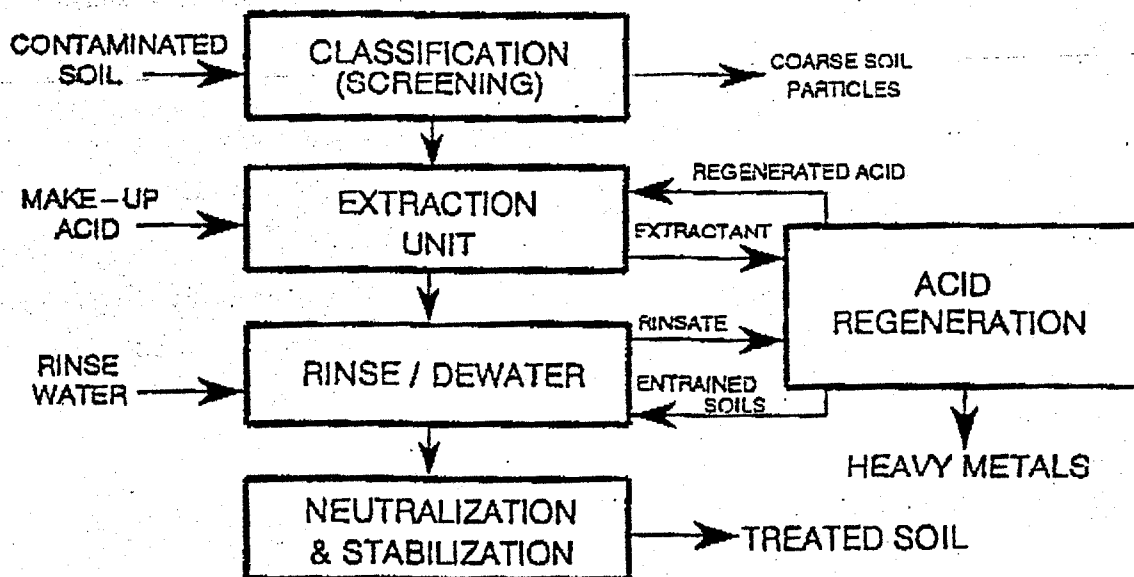
## INTRODUCTION

Through a Cooperative Agreement with the U.S. Environmental Protection Agency's Risk Reduction Engineering Laboratory, the Center for Hazardous Materials Research (CHMR) developed the Acid Extraction Treatment System (AETS). The project was conducted with support from Interbeton bv and The Netherlands Organization for Applied Scientific Research (TNO), located in the Netherlands. AETS is intended to reduce the concentrations and/or leachability of heavy metals in contaminated soils to render the soils suitable to be returned to the site from which they originated. Additional applications may include treatment of contaminated sediments, sludge and other heavy metal-containing solids.

The objective of the project was to determine the effectiveness and commercial viability of the AETS process in reducing the concentrations and leachability of heavy metals in soils to acceptable levels. This report represents an account of the activities conducted during the project, the experiments performed, and the results.

A pilot scale system was designed, constructed, and used to test different soils. Five soils were tested, including EPA Synthetic Soil Matrix (SSM), and soils from four Superfund sites (NL Industries in Pedricktown, NJ; King of Prussia site in Winslow Township, NJ; smelter site in Butte, Montana; and Palmerton Zinc site in Palmerton, PA). These soils contained elevated concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc.

Figure 1 AETS Block Flow Diagram



## PROCESS DESCRIPTION

A simplified block flow diagram of the AETS process is shown in Figure 1. Full-scale units are anticipated to be able to process between 10 and 30 tons per hour.

The first step in the full-scale AETS process is screening to remove coarse solids. These solids, typically greater than 4 mm in size, are anticipated to be relatively clean, requiring at most a simple rinse with water or detergent to remove smaller attached particles. If the soil contains a high percentage of clays, these may be removed as well for treatment separately.

After coarse particle removal, the remaining soil is scrubbed in an attrition scrubber to physically remove the metals and break up agglomerations. Then it is contacted with acid (HCl) in the extraction unit.

The residence time in the unit may vary depending on the soil type, contaminants and contaminant concentrations, but is anticipated to range between 10 and 40 minutes. The soil/extractant mixture is continuously pumped out of the mixing tank, and the soil and extractant are separated using hydrocyclones. The solids are piped to the rinse system, while the cyclone overflow (extractant) are treated using a proprietary technology which removes the metals and regenerates the acid.

The soils are rinsed with water to remove entrained acid and metals. The metals are removed from the rinsate using the same technology that regenerates the acid. After rinsing, the soil is dewatered using hydrocyclones and (if required) dewatering screens. In the final step, the soils are mixed with lime and fertilizer to neutralize any residual acid and return the soil to natural conditions.

## TEST PROCEDURES

This section describes the experimental procedures used with the pilot-scale AETS unit, which is capable of processing between 20 and 100 kilograms of soil per hour.

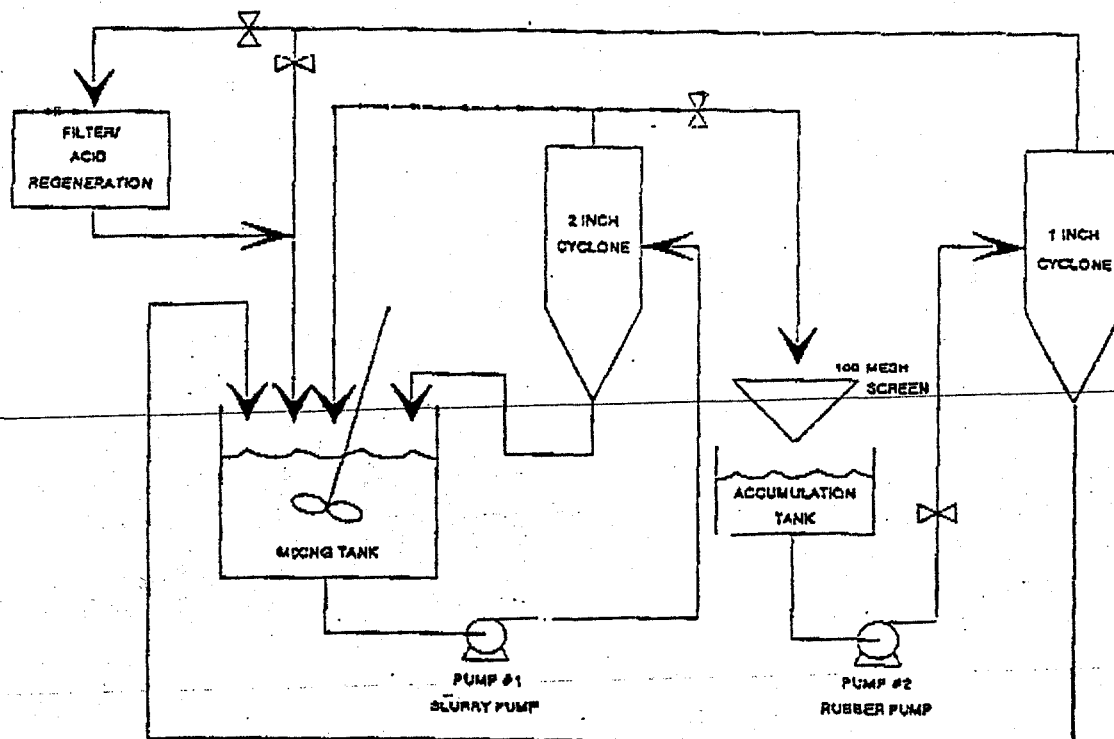
The soils were initially characterized for total and TCLP metals content. The soils were screened to remove the +8 mesh fraction on a mechanical shaker prior to being placed in the lab-scale attrition scrubber, where the soil was slurried with water or regenerated hydrochloric acid from previous experiments.

Next, the soil was contacted with hydrochloric acid for residence times between 10 and 40 minutes in the extraction tank. The pH of the mixture was maintained between 1.8 and 2.2. Figure 2 shows the flow diagram for the extraction step. During extraction, the solids were separated using two hydrocyclones, and returned to the extraction tank. The extractant was pumped to the acid regeneration system, and then returned to the extraction tank.

At the end of the experiment, the soil was dewatered using two cyclones and a mechanical shaker with a 200 mesh screen to separate the solids and the extractant. The extractant was then regenerated to be used as the acid in the next experiment, and the solids were prepared for the rinsing step.

The solids were rinsed in water to remove any residual acid. The metals were removed from the rinse water using a separate regeneration system than the one used during the extraction. The clean solids and all liquids were then analyzed for total and TCLP metals to form a material balance. The rinse water was ready for the next experiment, so no waste streams were generated.

Figure 2 Extraction Flow Diagram



## EXPERIMENTAL SOILS

This section gives a brief discussion of the five soils used during the laboratory- and pilot-scale investigations.

### Synthetic Soil Matrix

The Synthetic Soil Matrix (SSM) is produced by the EPA specifically for use in research and development of emerging or innovative technologies. The soil is a mixture of clay, silt, sand, gravel, and topsoil that is blended together to form the soil matrix. Organic and inorganic contaminants are added based on typical hazardous materials at Superfund sites. Table 1 lists the total and TCLP metals concentrations in the initial SSM.

Table 1. Synthetic Soil Matrix Contaminant Levels

Metal	Total Range (mg/kg)	TCLP Range (mg/L)
As	620 to 730	4.0 to 4.2
Cd	970 to 1,130	41.0 to 48.9
Cr	1,320 to 1,640	<0.05
Cu	10,900 to 12,400	297 to 298
Pb	10,040 to 10,800	26.0 to 27.1
Ni	980 to 1,410	35.6 to 35.9
Zn	20,500 to 26,300	669 to 719

#### NL Industries Site

The NL Industries site, located in Pedricktown, New Jersey, was an integrated battery breaking and lead smelting facility. The soil is contaminated with copper, lead, and zinc, but was chosen for this project due to the high levels of lead. The total and TCLP lead were 503 to 520 mg/L and 23,200 to 29,200 mg/kg, respectively.

#### King of Prussia Site

This site, in Winslow Township, New Jersey, was used to neutralize acid streams from an adjacent site. The soil is contaminated with chromium, copper, and nickel, and it is not hazardous by RCRA standards. The site was placed on the National Priorities List (NPL) because of high levels of chromium. Table 2 below describes the extent of contamination in the initial soil.

Table 2. King of Prussia Contaminant Levels

Metal	Total Range (mg/kg)	TCLP (mg/L)
Cr	1,020 to 1,390	0.20
Cu	1,240 to 2,030	7.10
Ni	335 to 518	27.6

#### Silver Bow Creek Site

This site, in Butte, Montana, contains a very sandy soil, with very little clay. The soil is contaminated with copper and zinc, with total metals ranging from 98 to 127 mg/kg, and 1,170 to 1,350 mg/kg, respectively. The TCLP range was from 1.4 to 1.7 mg/L for copper, and 2.6 to 7.1 mg/L for zinc. The Butte soil was non-hazardous soil, but still contained metals that needed removed.

### Palmerton Zinc Site

This site, located in Palmerton, Pennsylvania, was an old zinc smelting facility. Only one experimental extraction was conducted on this material, due to a lack of the soil. This soil was chosen due to its high levels of zinc, but also because it contained lead, cadmium, and copper. Table 3 summarizes the concentrations of the metals in the initial soil.

Table 3. Palmerton Soil Contaminant Levels

Metal	Total Metals (mg/kg)	TCLP Metals (mg/L)
Cd	137	2.60
Cu	166	0.16
Pb	898	0.66
Zn	9,150	71.0

### RESULTS

Table 4 and Table 5 summarize the results of tests using the five different soils, containing seven separate metals. The results indicate that the AETS process can reduce the concentrations of heavy metals and reduce the TCLP leachability levels to below current regulatory limits.

Table 4 summarizes the soil treatability across the soils and metals tested. Where individual soil fractions were separated during the extraction, and analyzed separately, the table shows the composite results if the entire soil had been remixed. The results show that AETS treated virtually all the soils tested to both reduce the total metals concentrations to below currently regulated concentrations and reduce the TCLP to below the currently regulated concentrations. The only exceptions were cadmium, which consistently failed the TCLP for SSM soil, and lead, which failed both the TCLP and total metals requirements for SSM soils.

Table 4. Qualitative Results of Extractions

Metal	Soil				
	SSM	Butte	King of Prussia	Pedricktown	Palmerton
As	*, T, L	*, T, L			
Cd	*, T				*, T, L
Cr	*, T, L		*, T, L	*, T, L	
Cu	*, T, L	*, T, L	*, T, L		*, T, L
Ni	*, T, L		*, T, L		
Pb	*	*, T, L		*, T, L	*, T, L

Zn	<b>*</b> , <b>T</b> , <b>L</b>	<b>*</b> , <b>T</b> , <b>L</b>		<b>*</b> , <b>T</b> , <b>L</b>	<b>*</b> , <b>T</b> , <b>L</b>
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\* - Metal is present in the soil

T - Successful treatment for total metals

L - Reduction in leachability to below standards

Bold and large fonts indicate high initial metals content (at least double regulatory standards)

Table 5 shows the results obtained from the lead contaminated soil from the NL Industries Superfund site in Pedricktown, NJ. The table shows over 90% reductions in total metals concentrations, and a 99% reduction in TCLP. Further work indicated that the TCLP and total lead in the soil could be reduced to below 5 mg/L and 1000 mg/kg, respectively.

Table 5. NL Industries Soil

Total Metals (mg/kg)			
Metal	Initial	Final	% Removal
Pb	29,200	1,310	95.5%

TCLP (mg/L)			
Metal	Initial	Final	% Removal
Pb	520	5.1	99.0%

The experimental work was completed during January 1993, and the final report has recently been issued.

## PROCESS ECONOMICS

Table 6 below shows the cost summary for AETS at several different process configurations. The table shows the effects of varying six critical parameters (feed rate, extraction time, percent fines, metals concentrations, site size and the number of sites treated with each set of equipment).

Table 6. AETS Cost Summaries Under Various Conditions

Process and Site Parameters					Amortized Capital and Operating Costs (\$/m <sup>3</sup> )
Feed Rate (yd <sup>3</sup> /hr)	Extraction Residence Time (min)	% Fines (< 50µm)	Metals Conc. (mg/kg)	Site Size (1000 yd <sup>3</sup> )	
30	24	15	5,000	150	77



20	24	15	5,000	100	96
20	36	30	15,000	60	138
20	24	15	15,000	80	118
15	24	15	5,000	60	122
15	36	30	15,000	30	193
15	36	15	5,000	30	168
10	36	30	15,000	20	241

The following notes apply to this table:

1. Plant is operating for only 1 eight hour shift per day.
2. No metal recovery value is assumed. All metal sludge is disposed.

Note that the table includes costs for mobilization, pilot plants, excavation, replacing soil, and reseeded the ground as well as soil treatment. Thus, the costs represent the *total costs* of treatment using the Acid Extraction Treatment System. Also note that the table conservatively assumes that the capital costs of the AETS system are amortized over only 1 or 2 sites, and that the plants operate only one 8 hour shift per day. Finally, the economic calculation assumes that the metal sludge is stabilized and disposed, and not reclaimed. The metals in many sites may be reclaimable. Relaxing all of these conservative assumptions will reduce the estimated treatment costs by 20 to 30%.

## CONCLUSIONS

The results of the study are summarized below:

- AETS is capable of treating a wide range of soils, containing a wide range of heavy metals to *reduce the TCLP below the RCRA limit and to reduce the total metals concentrations below the California-mandated total metals limitations.*
- In most cases, AETS is capable of treating the *entire* soil, with no separate stabilization and disposal for fines or clay particles, to the required TCLP and total limits. The only exception to this among the soils tested was with the SSM, which may require separate stabilization and disposal of 20% of the soil because of lead. This soil was successfully treated for other metals, including arsenic, chromium, copper, nickel and zinc.
- Costs for treatment, under conservative process conditions, range between \$80 and 240 per cubic yard of soil, depending on the site size, soil types and contaminant concentrations.

**INQUIRIES**

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*Excerpts from the full project report*

**ACID EXTRACTION TREATMENT SYSTEM  
FOR TREATMENT OF METAL CONTAMINATED SOILS**

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may be treatable using a 30 to 40-minute extraction, coupled with more extensive rinsing. Lead is treatable in the bulk of the soil provided that the fines (representing 20 to 25 percent of the SSM) are first removed. These fines may be amenable to treatment using different methods.

### 3.5 PEDRICKTOWN, NJ SOIL

#### Site History

This soil is from the National Lead Superfund site in Pedricktown, NJ. The facility crushed and processed lead-acid batteries through an on site furnace for lead reclamation. The soil is contaminated with copper, lead, and zinc, but was selected for testing primarily due to its high levels of lead.

#### Soil Description

The screening results and particle size distribution are given in Table 20 and Figure 9, respectively. The soil is sandy, with some clays and few large particles ( $>1/8"$ ) present. The raw soil is reddish in color with some visible clays. Eight percent of the soil would pass through a 150 micron screen. The density of the soil ranged from 1.58 to 1.89 g/cc. The average initial TCLP lead is 510 mg/L, and the average initial total lead is 26,200 mg/kg, which are high, even compared to the SSM. Table 20 shows the distribution of lead throughout the different fractions. The concentration of lead in the fines (-100 mesh) was extremely high (over 13 percent), but even the coarse fractions of the soil contained appreciable quantities of lead. The bulk of the lead (over 70 percent) was present in the fraction of soil between 150 and 850 microns in size.

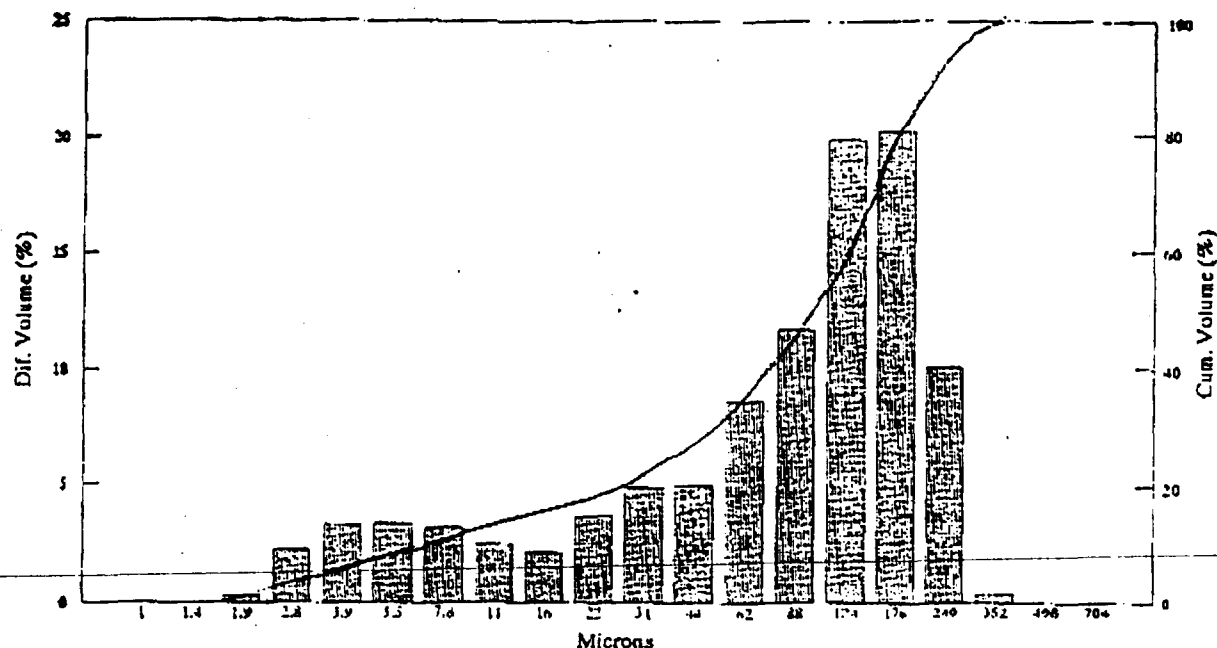
Table 20 Pedricktown, NJ, Screen Analysis

Mesh	Micron	Weight (g)	% on	Pb (mg/kg)
+5	4000	124 on	6.2%	12,000
+9	2190	160 on	8.0%	12,000
+20	841	342 on	17.1%	34,500
+40	420	550 on	27.5%	34,500
+60	250	458 on	22.9%	34,500
+100	149	216 on	10.8%	34,500
-100	N/A	160 thru	8.0%	132,000

Overall: 33,000

Microscopic examination revealed that the soil was very grainy, with orange-red particles throughout the granules. There were also many very dark particles mixed in with the soil. The bulk of the particles appeared to be beige or yellowish-orange in color.

**Figure 9 Pedricktown, NJ, Soil Particle Size Distribution**



### Discussion of Results

The removal data for the Pedricktown soil are given in Table 21 and 22. The AETS system dramatically reduced the TCLP lead in both extractions. The TCLP concentration was reduced by 95 percent in one experiment and by 99 percent in the other. During the first experiment, the concentrations were reduced to just above the RCRA limit of 5 ppm. Based on these results, CHMR anticipates that the TCLP can be reduced below the RCRA limit if a longer residence time is used. The rinse system for the treated soil malfunctioned during the second extraction. Inefficient rinsing tends to increase the TCLP values for the soil, because the entrained acid in the soil contains high concentrations of highly mobile metal contaminants. The high TCLP values for this soil were attributed to the problems with rinsing. However, a confirming experiment could not be performed because CHMR had insufficient soil.

The data for AE-107 shows that a 20 minute, one-step extraction can remove the majority of the lead from the Pedricktown soil. The residence time data from experiment AE-114 show that more than 90 percent of the lead was removed after only five minutes. The final total lead concentration is above the EPA surface soil limit, but well below the EPA limit for soils two feet below the surface. The total level is approximately equal to the California treatability limit for lead.

**Table 21 AE-107: Pedricktown Soil, 1st Experiment**

**Metal Removal Efficiencies from the Soil**

Metal	TCLP (mg/L)		% Removal	
	Untreated	2nd Ext	2nd Ext	
Pb	520.0	5.1	99.02%	

Metal	Total Metals (mg/kg)			% Removal	
	Untreated	1st Ext	2nd Ext	1st Ext	2nd Ext
Pb	29,200.0	1,430.0	1,310.0	95.10%	95.51%
Cu	192.0	92.3	68.3	61.93%	64.43%
Zn	239.0	345.0	195.0	NA	18.41%

NOTE: 1st extraction soil was dewatered and rinsed on the screen. The 2nd extraction soil remained in tank overnight, then rinsed on the screen.

**Table 22 AE-114: Pedricktown Soil, 2nd Experiment**

**Metal Removal Efficiency from the Soil**

Metal	TCLP (mg/L)		% Removal
	Initial	Final	
Pb	503.0	23.1	95.41%

Metal	Total Metals (mg/kg)		% Removal
	Initial	Final	
Pb	23,200.0	1,040.0	95.52%

**Timed soil samples**

Soil	Pb(mg/kg)
5 minute	1,790
10 minute	1,930
20 minute	2,210
30 minute	954
40 minute	1,080

The purpose of AE-114 was to find a suitable residence time for this soil. Although 95 percent of the total lead is removed after 5 minutes, some more studies may be needed to determine how long is necessary to reduce the TCLP lead to below acceptable levels.

As anticipated from the particle size distribution, the Pedricktown soils generated a

small amount of fines (less than 1 percent of the original soil). This material was not separately analyzed.

These results indicate that AETS has the potential for remediating the contaminated soil found on the Pedricktown site.

### 3.6 PALMERTON, PA SOIL

#### Site History

This soil is from the Superfund site in Palmerton, PA. The site is a mountain-side adjacent to the Zinc Company of America, a zinc smelting company. Because of deposition of zinc, cadmium, copper and lead, the mountain-side has become completely defoliated. The soil was chosen for testing because of high levels of zinc, and also because it contained some lead and cadmium. This soil is RCRA hazardous because of the cadmium level.

#### Soil Description

The particle size distribution is given in Figure 10. The Figure represents 15 percent of the soil, and so approximately 6 percent is under 20 microns. The soil was loam and sand, with some clays and large particles ( $> \frac{1}{8}$ " ) present. The soil was also blackish-brown in color with some visible yellow clays, tree bark, and vegetation. The soil is well-weathered, and most of the fines and organic content have been washed out over the years.

#### Discussion of Results

Only one extraction was performed using this soil because the project possessed only limited quantities. TCLP and total metals concentrations before and after the extraction are summarized in Table 23.

The soil was hazardous because of the cadmium TCLP levels. AETS reduced the cadmium TCLP value well below the limit. Zinc TCLP values were also reduced. Copper values remained about the same, and lead actually increased. This indicates that the extraction partially solubilized the lead, but did not efficiently remove it. Lead in this soil is expected to be in the form of sulfides, which are not easily solubilized.

The data in Table 23 shows that the only metal in excess of the federal limits was lead (over 500 mg/kg). Two metals exceeded the California total metals limits: zinc and cadmium. Extraction using AETS reduced the total zinc concentration by over 90 percent, and the residual was well within the prescribed limits. The extraction produced a similar 90 percent drop in cadmium levels, which were well within the prescribed limits. The total lead concentrations were reduced to very near, but still

## 4.0 CONCLUSIONS

The results indicate that the Acid Extraction Treatment System is capable of treating a wide variety of metals present in many different types of soil. Additional conclusions may be drawn regarding the treatment system design, and specific aspects of the technology. These are discussed in subsequent sections. In addition, a final treatment system design is presented, and an economic analysis of it is given.

### 4.1 SOIL AND METAL TREATABILITY

Table 26 summarizes the soil treatability across the soils and metals tested. Where individual soil fractions were separated during the extraction, and analyzed separately, the table shows the composite results if the entire soil had been remixed. The results show that AETS treated virtually all the soils tested to both reduce the total metals concentrations to below currently regulated concentrations and reduce the TCLP to below the currently regulated concentrations. Major exceptions included cadmium, which consistently failed the TCLP for SSM soil, and lead, which failed both the TCLP and total metals requirements for SSM soils. Lead was also not reduced below the EPA surface soils concentration (500 mg/kg) for the Pedricktown soil, although it was reduced below the EPA subsurface and California total metals concentrations.

Table 26 Qualitative Results of Extractions

Metal	Soil				
	SSM	Butte	King of Prussia	Pedricktown	Palmerton
As	* , T , L	* , T , L			
Cd	* , T				* , T , L
Cr	* , T , L		* , T , L	* , T , L	
Cu	* , T , L	* , T , L	* , T , L		* , T , L
Ni	* , T , L		* , T , L		
Pb	*	* , T , L		* , T , L	* , T , L
Zn	* , T , L	* , T , L		* , T , L	* , T , L

Key: \* -- Metal is present in that soil  
 T -- Successful treatment for total metals  
 L -- Reduction in leachability to below standards.  
 Boldface and larger fonts indicate high initial metals concentration (at least double the regulatory standards)

The total lead result for the Pedricktown soil is not surprising: the soil started with nearly 3 percent lead, which was reduced to approximately 0.1 percent during a



single-step extraction. A second extraction is probably necessary to reduce the total concentration further.

Neither the total lead concentrations nor the TCLP lead concentrations were reduced to below the regulatory limits during the extractions using the entire SSM soil. They were reduced, however, during earlier extractions using only the coarse fraction of the soil. Based on the results of the extractions, it appears that if the finest 20 percent of the soil had been removed, the remaining soil would have been treatable using AETS. CHMR is currently performing some experiments using the fines fractions to determine if alternative extraction procedures could be used to remove lead from the fine fractions of the soil.

The cadmium result for SSM is extraordinary in that the portion of the soil which failed the TCLP for cadmium was the coarse fraction (+ 100 mesh). The fines passed the TCLP. Most probably, the TCLP level in the coarse fraction could be reduced if a longer extraction time were used. The Palmerton soil demonstrates that cadmium is treatable using AETS -- the soil is hazardous only because of the TCLP value for cadmium, and that was reduced by over 90 percent using AETS.

## 4.2 AETS PROCESS DESIGN

Based on the results of the experiments, the basic design of the AETS process is unchanged from that shown in Figure 1. The results have provided further information and clarification concerning the following aspects of the required design.

- Soil Pretreatment System
- Extraction System
- Dewatering and Rinse Systems
- Acid Regeneration System
- Post-treatment System

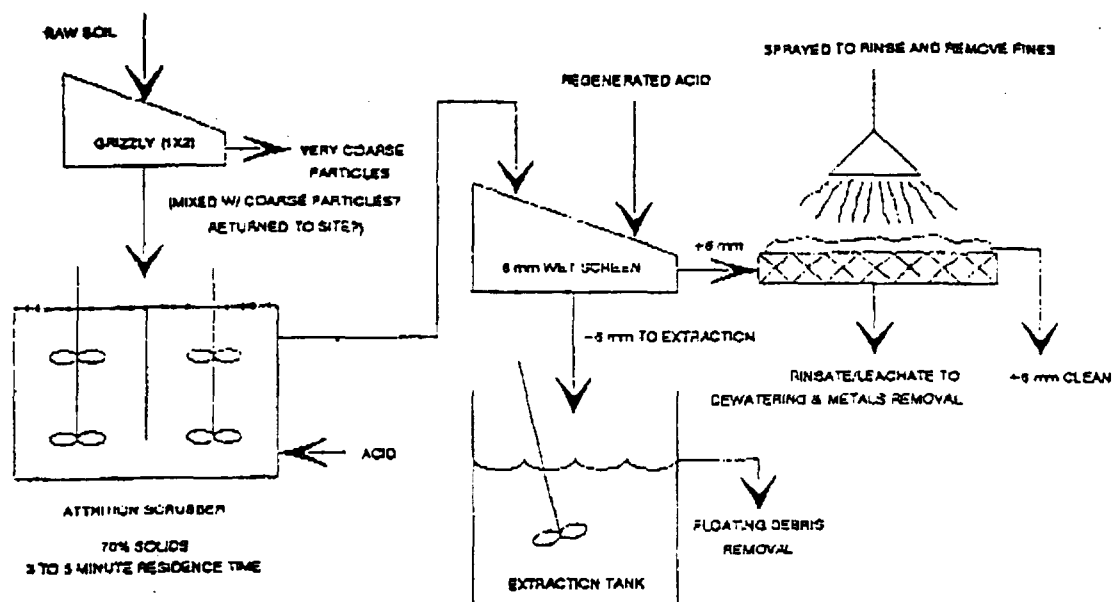
These components are discussed below.

### Soil Pretreatment System

The soil pretreatment system is shown in Figure 11. The soil is first passed through a grizzly, designed to remove particles larger than about 1 by 2 inches in size. The underflow from the grizzly passes directly into an attrition scrubber, which is operated at relatively high solids to liquid ratios. If makeup liquid is required in the scrubber, it may be supplied as regenerated acid from the extraction system. In the final section of the scrubber, more liquid may be added if necessary to further slurry the soil and make it easier to sieve.

Once through the scrubber, the soil passes directly onto a 6 mm wet screen. The wet screen is sprayed with acid from the regeneration or extraction systems. The

Figure 11 AETS Pre-treatment



overflow from the screen includes coarse gravel and bits of trees and other material, which will be allowed to drain on a pad, and may possibly be rinsed to remove excess small particles clinging to larger ones. The drainage from the coarse particles will either be passed directly back onto the screen, or (if it is rinsewater), may be clarified, treated to remove metals, and reused.

The underflow from the 6 mm screen will be placed directly into the extraction tank for further processing.

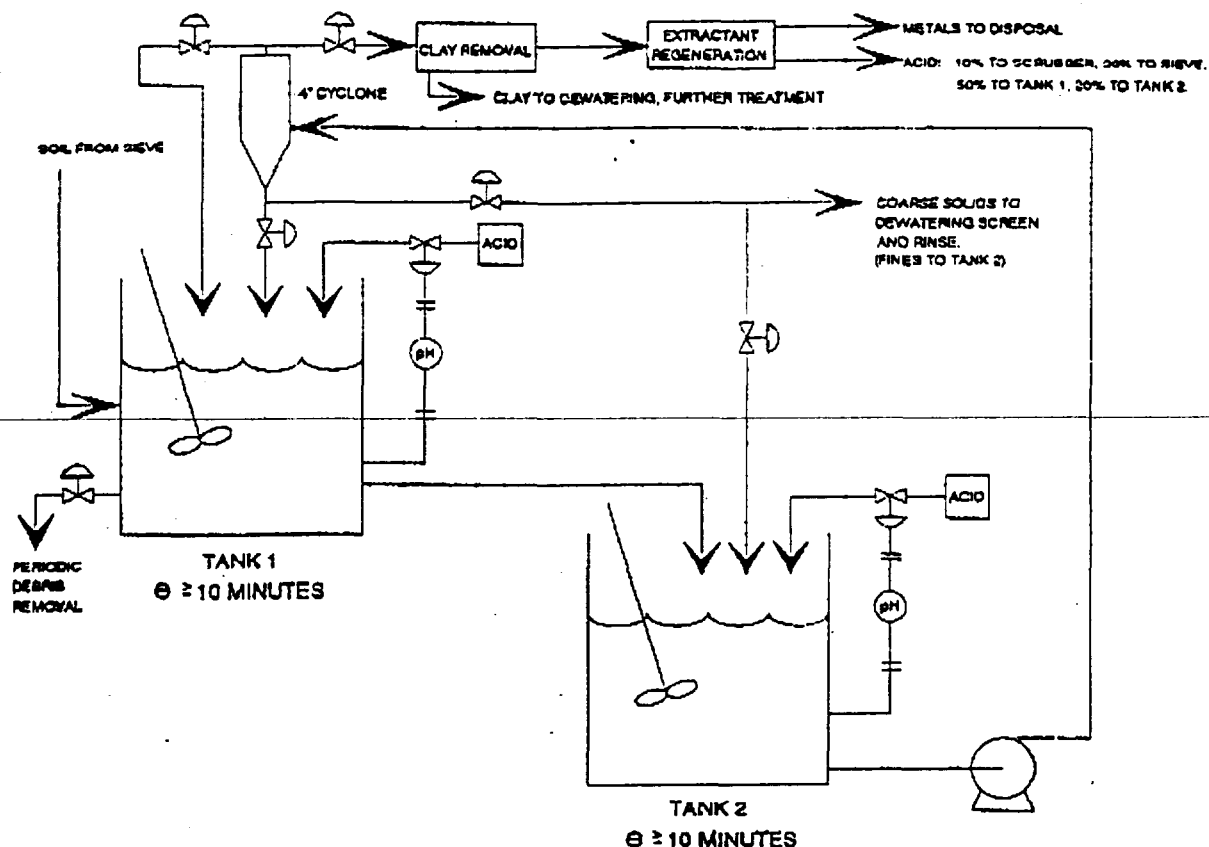
The very coarse materials originally removed in the grizzly may or may not be contaminated. If they are, they may be rinsed with the coarse particles (if necessary to remove dirt and other clinging debris), or washed using debris washing techniques. If they are uncontaminated, they can be returned directly to the site.

### Extraction System

The extraction system consists primarily of a tank, or series of tanks, which provide the soil with the appropriate contact time with acid. The tanks are well-mixed to prevent solids from settling during the extraction. The soil is extracted at approximately 20 percent by weight solids.

Figure 12 shows one possible system. The soils are fed to two extraction tank system in series, which are intended to overcome problems associated with the residence time distribution in continuously stirred tank reactors. Additional residence time will be provided by the scrubber and sieving systems.

Figure 12 Extraction System



The soil slurry passes from the first tank to the second, then to a hydrocyclone. The pilot plant used 2-inch hydrocyclones. Subsequent discussions with vendors and experts on hydrocycloning suggest that a 4-inch cyclone may provide a better split. Therefore, the system is drawn using 4-inch cyclones. These will be manifolded together as required for the system flow. Both the overflow and underflow from the cyclone may be split, depending on the requirements of the individual soil. A portion of the overflow may pass directly into Tank 1, depending on the capacity of the clay dewatering and acid regeneration systems. It is anticipated that sometimes, particularly during start up, a portion or all of the underflow may also be cycled back to Tank 1 and/or Tank 2. Otherwise, the underflow will pass to the coarse solids dewatering and rinse system.

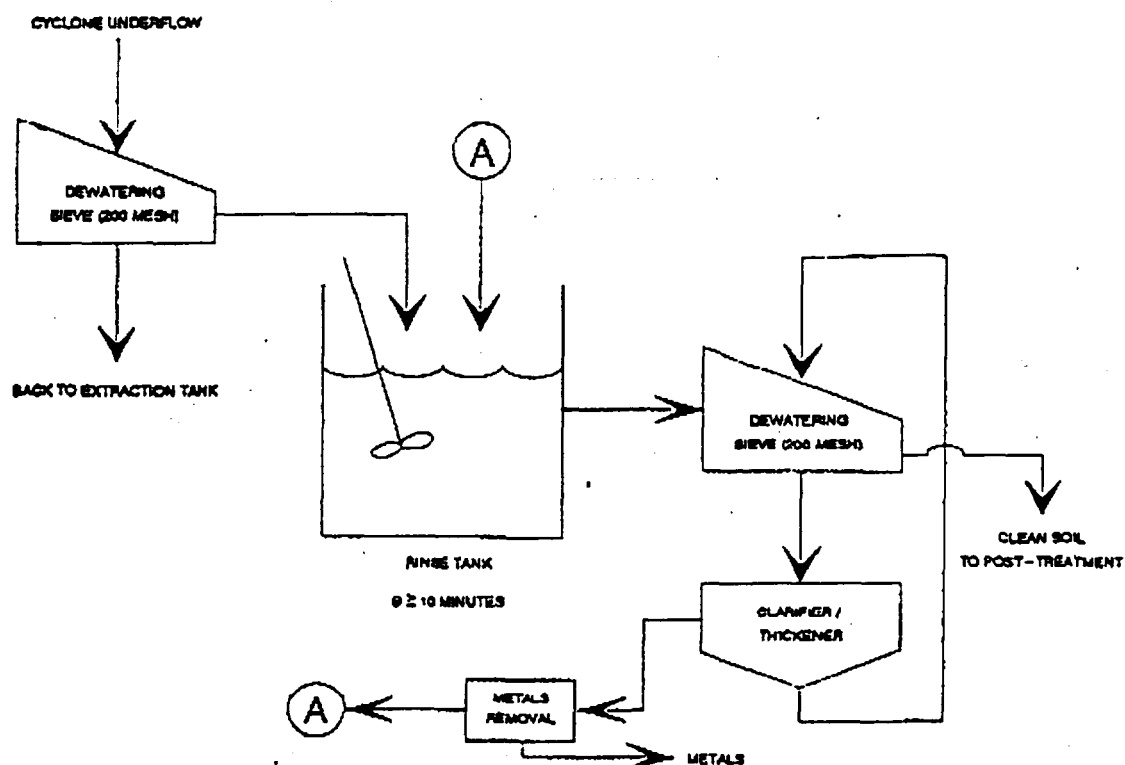
The overflow, meanwhile, will be clarified to remove clays and other solids. Then the acid extractant will be regenerated. It is anticipated that approximately one-half of the regenerated extractant will be passed directly back into Tank 1. The remaining portion will be split among the scrubber (~ 10 percent), the sieve system (25 percent), and Tank 2 (15 percent).

#### Rinse and Dewatering Systems

AETS is anticipated to require two rinse and four dewatering systems. Rinses will be required for both the fine and coarse solids. Dewatering will be required of both the fines and coarse solids both before and after they are rinsed.

A dewatering and rinse system for the coarse solids is shown in Figure 13. The system consists of a 200 mesh dewatering sieve, followed by a rinse tank, and a second sieve system. The underflow from the dewatering sieve, which will contain some fines, is passed back to the extraction tank. The fines are anticipated to build up in the extraction tank and to be removed with the sieved solids.

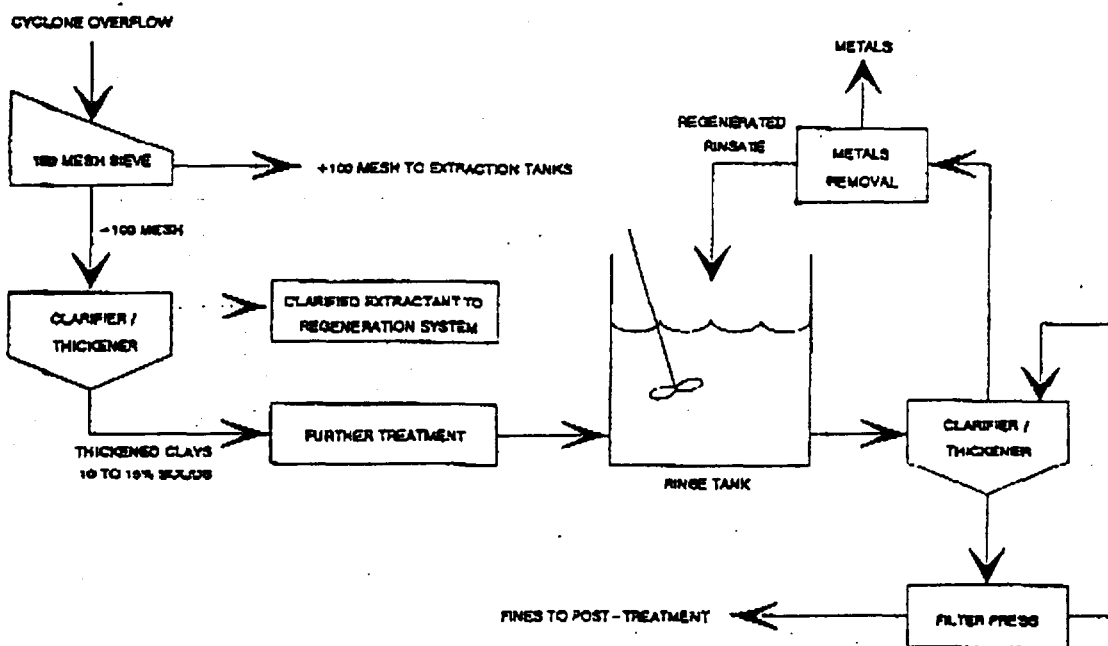
Figure 13 Coarse Solids Dewatering and Rinsing System



The overflow from the dewatering sieve is passed into a rinse tank, where it is rinsed and well-mixed for 10 minutes or more. From there it passes to a second dewatering sieve, also 200 mesh. The underflow from this sieve is flocculated and clarified. The solids from the floc tank are carefully placed atop the dewatering sieve for removal with the clean soil. The clarified rinsate is further processed to remove the metals and then recycled to the rinse tank.

The fines dewatering and rinse system is shown in Figure 14. The fines are first sieved to remove any particles larger than 100 mesh, which are returned to the extraction tank. They are then sent to a clarification unit, and allowed to flocculate. The clarified extractant is regenerated and returned to the extraction system. The thickened clays are further treated (if necessary), then rinsed, and thickened again. The clarified rinsate is treated to remove metals, then returned to the rinse system. The thickened, rinsed clays are further thickened in a filter press and sent to soil post-treatment.

Figure 14 Fines Dewatering and Rinsing



### Acid Regeneration System

AETS employs a proprietary acid regeneration system.

### Soil Post-Treatment

The purpose of soil post-treatment is two-fold: to remix soil fractions which have become separated during processing and to return the soil to its native condition.

The soils are anticipated to be remixed using front-end loaders or other earth-moving equipment. The soils will be mixed with a small amount of lime to return the soil buffering capacity. In addition, fertilizers and topsoil may be added. Experiments to determine the exact post-treatment requirements are on-going.

It should be emphasized that the TCLP results to date have not included any post-treatment. It is anticipated that the addition of lime, and other neutralizing agents will help stabilize the metals in the soils. In addition, any significant addition of topsoil or fill will dilute both the TCLP and total metals results. Neither lime nor topsoil were added during the experimental program, and their addition is not included in a determination of whether or not the AETS treated soil is hazardous.

## 5.0 AETS ECONOMICS

To estimate the economics of remediating a site using AETS, capital and operating costs for various sized and configured systems were determined. These are summarized in Table 27.

**Table 27 AETS Cost Summaries Under Various Conditions**

Process and Site Parameters						Costs		Total Cost per yd <sup>3</sup>	
Feed Rate yd <sup>3</sup> /hr	Extraction Res. Time (min)	% Fines ( $<50\ \mu\text{m}$ )	% of Fines Disposed	Metals Conc. (mg/kg)	Site Size (1000 yd <sup>3</sup> )	Capital Costs (million \$)	Operating Costs (\$/yd <sup>3</sup> )	Capital paid off over one site (\$/yd <sup>3</sup> )	Capital paid off over two sites (\$/yd <sup>3</sup> )
30	24	15	2	5,000	150	4.5	41	83	71
20	24	15	2	5,000	100	3.6	51	104	88
20	36	30	25	15,000	60	4.5	82	178	147
20	24	15	25	15,000	80	4.1	71	141	121
15	24	15	2	5,000	60	3.2	61	133	111
15	36	30	25	15,000	30	3.8	92	243	191
15	36	15	2	5,000	30	3.3	81	189	146
10	36	30	25	15,000	20	3.2	112	301	237

Notes: 1. Plant is anticipated to operate only 1 shift per day  
2. No metal recovery value is assumed; all metal sludges are disposed.

## 5.1 COST CALCULATIONS

Capital costs were calculated by summing the following:

- General Costs** Including site preparation, pilot work, trailers, and permitting. These represent approximately 8 to 11 percent of total Capital Costs.
- Pretreatment** Costs associated with coarse and very coarse removal, scrubbing, and coarse rinsing/processing. (11 to 15 percent of total capital).
- Extraction Cost** Costs associated with contacting the soils with acid, including hydrocycloning the soil (7 to 9 percent)
- Acid Regeneration** Costs associated with metals removal and acid reformation. (31 to 41 percent)
- Dewater/Rinsing** Costs associated with dewatering and rinsing coarse solids and thickening and processing fines. (21 to 25 percent)

Soil Post-treat	Costs associated with mixing, post-treatment and fertilization. (3 to 4 percent)
Miscellaneous	Costs associated with other required piping, instruments, etc. (7 to 9 percent)

The costs for each element were increased by 10 percent for engineering, 23 percent for transportation and final installation costs, 5 percent for start up and shakedown costs, 2 percent for spare parts, and 10 percent for contingency. The most uncertain costs were those determined for the regeneration system. To the extent possible, these costs were overestimated, so that the final unit costs were conservatively determined.

Operating costs included labor (a total of between 3 and 4 operators, plus a supervisor, 2 to 4 excavators (with excavation equipment), a health and safety officer, maintenance and engineering), maintenance equipment costs, utilities, chemicals, disposal, and reseeded.

The capital and labor costs were combined by assuming a 10 percent cost of capital; depreciation over either 1 or 2 years; operations 1 shifts per day (2000 hours/year) for one year per plant site; moving and reassembly costs of \$150,000 plus 15 percent original capital (if the plant is depreciated over two years); and plant downtime of 10 percent of operating hours for unanticipated shutdowns (i.e., equipment failure).

## 5.2 COST SUMMARY

Table 27 gives a cost summary for AETS at several different process configurations. The table shows the effects of varying six critical parameters (feed rate, extraction time, percent fines, percent fines disposed (rather than treated), metals concentrations, site size and the number of sites treated with each set of equipment).

Note that the table includes costs for mobilization, pilot plants, excavation, replacing soil, and reseeded the ground as well as soil treatment. Thus, the costs represent the *total costs* of treatment using the Acid Extraction Treatment System.

For 15 and 20 cubic yard per hour plants, the table gives the cost under best conditions (first row), cost under worst conditions (second row), and cost under intermediate conditions (third row). The table also gives the cost under best conditions for the largest plant anticipated (30 yd<sup>3</sup>/hr), as well as the cost under worst conditions for the smallest plant anticipated (10 yd<sup>3</sup>/hr). In this way, the table should bracket the costs. For reasonably sized plants, the anticipated treatment costs range between \$100 and 180 per cubic yard.

The costs for the most commonly employed alternative (stabilization and disposal), range between \$180 or \$450 per cubic yard, depending on the size and



circumstances of the site, with typical costs about \$250 per cubic yard. Thus, AETS is generally competitive with stabilization and disposal. It is also a more environmentally sound alternative because of the potential for reclaiming the metals found at the site.